

WWW-based Interfaces to Clinical Information Systems: The State of the Art

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Nine WWW-based interfaces to clinical information systems were reviewed. Five have progressed past the proof of concept phase and into alpha testing in the clinical environment. All key features desirable in an advanced clinical information were present in at least one interface, however many implementations were rudimentary. Much human computer interface research and WWW tool development needs to occur before implementation of a WWW-based interface to a clinical information system should be considered for a mission-critical, production environment.

INTRODUCTION

The computer interface serves as an intermediary between a healthcare provider and a clinical information system¹. At a minimum, the interface should provide access to data and allow clinicians to document their actions and the patient's condition. A state-of-the-art interface should act as a communication medium synthesizing and presenting patient-specific clinical information at the time and place it is needed. It should allow clinicians to formulate a plan of action and send messages directing the appropriate personnel collaborating in the care of the patient².

The world-wide web (WWW) is one of the most exciting innovations to hit the computing and communications community. Each day over 15,000 hosts, many containing new applications and information resources, are added to this world-wide computer network³. The extreme ease of use of WWW applications - click on highlighted links to access more information - coupled with seemingly ubiquitous access via the Internet and free browsing software has lead to unprecedented growth in both the number and nature of its applications⁴.

There are multiple reasons why developers have chosen WWW-based interface development tools to create their next generation of clinical information systems. First, it is relatively easy and inexpensive to

create working prototypes of result review applications which can be used to generate interest among clinicians and administrators. Second, the cross-platform nature of the WWW client browsers eliminates the problems of maintaining multiple versions of interface software. Third, client maintenance, always a challenging problem in a large institution, is reduced significantly since the "look and feel" of the application along with all functionality is controlled from the server. Fourth, since most institutions are currently using their WWW interfaces on an intranet, i.e., behind a firewall, many of the security concerns surrounding the WWW do not apply.

Application developers are constantly faced with the decision of when to begin using new technology. Move too soon and risk having to backtrack out of a blind alley due to a technology that fails to mature as planned. Move too late and risk being left in the dust as your competitors race ahead. We undertook this study to ascertain the state of the art for WWW-based interfaces to existing clinical information systems to answer the question: "Is WWW technology ready to be used in a large-scale, mission-critical integrated healthcare delivery system's production environment?"

BACKGROUND

Before one can begin to answer such a complex question, one must identify key elements and/or functions which define such an environment. We identified 5 major categories of functionality that an interface to an advanced clinical information system should provide access to: 1) results review; 2) charting and documentation; 3) advanced e-mail for communications; 4) patient list management; and 5) educational/reference material. Within each of these broad categories we identified specific features that if present would enable a clinician to obtain enough information to help care for a patient. In addition to these key features, the system must provide security so that unauthorized access is denied, both to protect patient confidentiality as well as system integrity.

METHODS

We identified a set of key or desired features that a state-of-the-art interface to a clinical information system should provide (see Table 1). This feature set was based on a review of the literature and on our experiences working with the HELP hospital information system at the LDS Hospital⁵ and the Brigham & Women's Hospital's Integrated Computing System (BICS)⁶. For each feature we developed a concise definition.

We identified WWW-based interfaces to clinical information systems using Digital Equipment Corporation's Alta Vista search engine (<http://altavista.digital.com>) (see Table 2). We included any site which presented patient-specific clinical data in any form. We did not require

that the system be in routine clinical use or freely accessible over the Internet. For example, Regenstrief, Columbia, Children's Hospital, and UC Davis have systems running using live patient data and do not usually permit unrestricted access via the Internet. We were able to gain special permission to access these systems for a short period of time using test patient data. We did not include sites which presented only educational or reference resources or access to an expert system without an attached patient database.

We explored each site (see Table 2) and noted which of our key features were present. Following our review of each site we sent our findings to a researcher at each institution for confirmation. Disagreements on terminology and/or functionality were worked out via email and phone conversations.

Table 1. Definitions of Key Features

FEATURE	DEFINITION
Results Review	
Identify Patient	allows clinicians to identify particular patients based on various features (scale: 1-4 one point given for each method of identification) - e.g., name, medical record number, location, physician, diagnosis, schedule, etc.
Medications	displays a list of the current medications including dose, route and date(s) ordered
Problem List	displays a list of the patient's medical problems
Clinical Summary	displays a one screen view of patient status (i.e., lab values, medications, problems, allergies).
Problem-specific summary	show clinical data relevant to a particular problem.
Detailed views	demographic or laboratory specific in-depth views of data - e.g., demographics - name, address, date of birth, sex, insurance coverage, etc..
Full-text searching	allows a clinician to search the text of all reports for a text string
Charting/Documentation	
Clinical data	allows a clinician to enter data describing the patient
Order entry	allows a clinician to enter data to generate an order
Communication	
Integrated e-mail applications	provide modifiable e-mail templates to clinicians
Computer generated messages	patient-specific messages automatically sent to clinicians and/or patients
List Management	
Patient list management	allows a clinician to maintain a list of patients they are responsible for
Sign-Out	allows a clinician to transfer responsibility for a patient(s) to another clinician
Educational/Reference Material	
Educational resources	e.g., on-line textbooks, clinical guidelines, teaching files of images, etc.
Institutional directories	e.g., directory of consultants, referring physicians, or phone book

Table 2. Universal Resource Locators for WWW Sites Reviewed

SITE	COMMON NAME	URL
BCH	Boston Children's Hospital	http://www.emrs.org/medweb
CPMC	Columbia Presbyterian Medical Center	http://www.cpmc.columbia.edu/cisdemo/query.html
DSG	Decision System's Group	http://dsg.harvard.edu/public/intermed/scamc95/DSGLogin.html
Ind.	Regenstreif Medical Center	http://FALCON.IUPUI.EDU:8120/
MDNJ	Medical & Dental College of New Jersey	http://www.laurie.umdj.edu/
MGH	Massachusetts General Hospital	http://www.lcs.mgh.harvard.edu/rpiademo/start.htm
UCD	UC Davis - Veterinary College	http://www.vmeth.ucdavis.edu
UVa	University of Virginia	http://vemr.virginia.edu/demo/homepg.html
WVU	West Virginia University	http://berwind.cerc.wvu.edu/lpi-bin/layoutServer
HELP	LDS Hospital	NO WWW INTERFACE EXISTS; included for comparison only
BICS	Brigham & Women's Hospital	NO WWW INTERFACE EXISTS; included for comparison only

RESULTS

Table 3 shows the results of our review; features provided by HELP and BICS are shown for comparison purposes only. Of the 9 WWW sites, five (CPMC⁷, BCH⁴, IND, UCD, WVU⁶) have progressed past the proof of concept phase and into alpha testing in the clinical environment. Three sites were created as demonstrations for specific departmental functions only (DSG and UMNJ for Radiology and UVA⁹ for Neurosurgery). The MGH site was designed to provide a subset of clinical data for review by referring physicians.

All sites provided one or more ways to identify and display demographic information about a patient. Eight sites presented laboratory data in one form or another, although the richness and diversity of the implementations differed greatly between sites. Only 2 sites (CPMC, BCH) had a graphical display for laboratory data and only CPMC could generate and display data-driven alert messages based on laboratory values. The five sites that had progressed into clinical testing made other clinical data (e.g., medications, problem lists) available for review. Eight sites had both a browser and viewer for freetext reports; two sites (UMNJ, DSG) had the capability to search across patients through all reports for a specific text string. Five of the nine sites had begun to utilize the graphic capabilities of the WWW to display image data.

Clinical data entry features were only available on three systems (CPMC, WVU, DSG) and were limited to short text entry fields and check boxes. No site

had yet implemented order entry. Desirable advanced communications functionality and patient list management were available at only three sites. Five of the nine sites had links to other educational resources available on the WWW; two (CPMC, BCH) had context-sensitive links to Medline other reference resources.

DISCUSSION

It is feasible to create a WWW-based interface to a clinical information system. Our review shows that every desirable interface feature we originally identified has been implemented in at least a rudimentary version in at least one of the nine sites.

However, several hurdles stand in the way of these interfaces reaching their full potential as clinical intermediaries. First, the visual appeal and clarity of the interfaces fell below the expectations generated by current state of the art commercially available PC-based software. Reasons for this include: 1) lack of flexibility in current WWW browsers and the Hypertext Markup Language (HTML), 2) the early stage of development of each site, and 3) current WWW technologies facilitate rapid prototyping, but implementation of advanced features may be more difficult than with other currently available visual interface design tools¹⁰. Second, as the name "browser" suggests, navigating through these systems for the purpose of data review is easy. However, building complex clinical data entry features may be more difficult. Third, the stateless nature of the HTTP protocol makes implementation of context

Table 3. WWW-based Interfaces to Clinical Information Systems: The state of the Art

✓ - has feature * - in clinical use ± - data exists; not grouped this way	CPMC	BCH	WVU	IND	UCD	UVA	DSG	UMNJ	MGH	HELP	BICS
General Features:										(non-WWW)	
Identify patient	4	2	1	4	2	2	2	2	2	4	4
Patient Demographics	4	4	4	4	4	4	1	3	2	4	4
Results Review											
Laboratory Data:											
Chem/Heme/Urine analysis	✓	±	±	✓	✓	✓			✓	✓	✓
Micro/Path/Blood bank	✓	±		✓	✓	✓			✓	✓	✓
Tabular display	✓	✓		✓	✓	✓			✓	✓	✓
Variable time range for display	✓	✓		✓						✓	✓
Graphical display	✓	✓									
Values >< normal ranges flagged	✓			✓		✓				✓	✓
Normal ranges shown	✓	✓							✓	✓	✓
Units shown	✓	✓		✓	✓				✓	✓	✓
Lab comments	✓			✓	✓	✓				✓	✓
Data-driven messages	✓									✓	✓
Other Clinical Data:											
Medications	✓	✓	✓	✓						✓	✓
Problem list	✓	✓	✓	✓	✓					✓	✓
Clinical Summary	✓	✓		✓	✓					✓	✓
Problem-specific summary		✓	✓	✓							✓
Free-text reports:											
Browser	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
Report viewer	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Full text searching							✓	✓			
Images:											
Scanned notes			✓								
Radiology studies	✓		✓	✓			✓	✓			✓
Charting/Documentation											
Clinical Data entry	✓		✓				✓			✓	✓
Order entry										✓	✓
Data driven alerts	✓									✓	✓
Communications											
Integrated e-mail applications			✓								
Computer generated messages	✓									✓	✓
List Management											
Patient list management	✓				✓						✓
Sign-Out											✓
Educational/Reference Material											
Context-sensitive links - Medline	✓	✓									
Access to educational resources	✓	✓					✓	✓			✓
Access to institutional directories								✓			✓

sensitive queries difficult. In addition, the sites have only begun to exploit fully the power of the Internet to provide ubiquitous access to their data and links to other information resources. Current perceptions surrounding the inability of current WWW technology to provide secure data transfer has lead

the alpha test sites to prevent access via the Internet. Until these perceptions change or the technology improves these benefits of the Internet will not be realized. Also at most sites, the techniques by which data are transferred from host to intermediate databases convert the information from coded to

freetext reports. Therefore the ability to provide context-sensitive links to other information resources is lost. Preserving the "meaning" of the data is difficult, but mandatory if the full power of the information resources available on the Internet are to be exploited.

While many of these limitations are promised to be remedied in future versions of the browsers and/or servers, this is by no means guaranteed. The additions of the new programming languages Java¹¹ and JavaScript¹² may solve many interface problems.

CONCLUSION

Current versions of WWW-based interfaces are in their infancy. All key features desirable in an advanced clinical information were present in at least one interface, however many implementations were rudimentary. Much human computer interface research and WWW tool development needs to occur before implementation of a WWW-based interface to a clinical information system should be considered for a mission-critical, production environment.

Acknowledgments

A special thanks to the following individuals who were kind enough to make their WWW sites available to us for this review: Marc Overhage - Regenstrief; Tad Davis - West Virginia; Soumitra Sengupta - Columbia; Jim Self - UC-Davis. Zak Kohane - Boston Children's Hospital. See www.cpmc.columbia.edu/edu/medinfoemrs.html for an online list of these clinical information system demonstrations on the WWW.

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